

***Leptopsalis foveolata* sp. n., a new species of Stylocellidae from Thailand that displays a novel morphological feature in the suborder Cyphophthalmi (Arachnida, Opiliones)**

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***Leptopsalis foveolata* sp. n., a new species of Stylocellidae from Thailand that displays a novel morphological feature in the suborder Cyphophthalmi (Arachnida, Opiliones).** - *Leptopsalis foveolata* sp. n., a species of Southeast Asian mite harvestman with an exceptional morphology, is described. Males and females of this species bear rows of deep pits on the dorsal and ventral side of the posterior end of their body. These pits are strongly granular but do not bear obvious pores or especially dense concentrations of micropores. Also, many of the large granules on the body surface are flattened and digitated, and many around the pits are grooved. This is a new morphological feature in the suborder Cyphophthalmi, and its function is not clear. The species is only known from the type locality, Mt Sankalakheeree in Pattani Province, southern Thailand, formerly known as Bukit Besar.

Keywords: Taxonomy - mite harvestmen - opisthosomal pits - Namtok Sai Khao - Bukit Besar.

INTRODUCTION

Stylocellidae is a family of Cyphophthalmi that can be found from the Eastern Himalayas to New Guinea and out to the Philippines, and which likely arrived in Southeast Asia on the Sibumasu terrane that rifted from the northern Gondwanan coastline in the Paleozoic (Clouse & Giribet, 2010). Cyphophthalmi in general are small harvestmen that favor humid leaf litter and caves, and which, until recently, were poorly understood and not commonly collected. Now that their remarkably poor dispersal abilities have been shown to make them excellent models for vicariance biogeography (Boyer *et al.*, 2007; Giribet *et al.*, 2012), and as collecting techniques have improved, new collections of Cyphophthalmi have become more routine (Giribet, 2000). These collections have revealed considerable biodiversity, especially in tropical families (Benavides & Giribet, 2007; Clouse & Giribet, 2010). Moreover, not all of these new species differ by subtle body proportions (copulatory organs are still poorly

investigated); some present entirely new morphological features, as in the species we describe here.

Stylocellid taxonomy has recently been updated after the publication of several new phylogenetic hypotheses (Clouse *et al.*, 2009; Clouse & Giribet, 2010; Giribet *et al.*, 2012). Twenty-seven of the family's 34 described species had been placed in the genus *Stylocellus*, four in *Fangensis*, and the remaining three distributed one each in *Leptopsalis*, *Miopsalis* and *Meghalaya* (Clouse & Giribet, 2007; Giribet, 2000; Giribet *et al.*, 2007; Schwendinger & Giribet, 2005). *Leptopsalis beccarii* Thorell, 1882 (the type of that genus) was in the synonymy of *Stylocellus sumatranus* Westwood, 1874 (see Thorell, 1890) for about a century, but it has been resurrected (informally in Clouse *et al.*, 2009 and in Giribet, 2002; formally after examination of types in Clouse & Giribet, in press) and will soon receive fourteen species transferred from *Stylocellus* (Clouse, in press; Clouse & Giribet, in press). It is now understood that *Leptopsalis* encompasses the bulk of the family's undescribed diversity, including all species on Sulawesi, New Guinea and Java, as well as most species on Sumatra and the Thai-Malay peninsula (Clouse & Giribet, 2010). The species described here is the first to be originally assigned to *Leptopsalis* in 130 years.

The types of the new species were collected at Sai Khao Waterfall, at the foot of Mt Sankalakheeree (or Sankalakhierie) which peaks at ca 1000 m altitude. This is an isolated, still densely forested granite mountain massiv at the border of Pattani, Yala and Songkhla Province, known under the Malay names "Bukit Besar" (= big hill) and "Gunong Negiri" before the Sultanate of Pattani came under Siamese rule in 1909. Bukit Besar was sampled by the "Skeat-Expedition" in May 1899 (Skeat, 1954) and by the "Annandale & Robinson-Expedition" (N. Annandale took part in both expeditions) in April-May and August-September 1901 (Annandale & Robinson, 1903). The discovery of a velvet-worm (probably *Eoperipatus* sp.) on Bukit Besar during the "Skeat-Expedition" highlights the presence of typical Malayan faunal elements. Other such elements (of arachnids) await publication.

MATERIALS AND METHODS

Legs, tarsi, and various details were photographed on an FEI Quanta 200 (www.fei.com) scanning electron microscope (SEM). Color photographs were taken under a Leica MZ 12.5 stereomicroscope (www.leica-microsystems.com) with a mounted JVC KY-F70B digital camera (www.pro.jvc.com), where images were captured at different focal planes and then assembled using the application Auto-Montage Pro Version 5.00.0271 by Syncroscopy (www.syncroscopy.com).

We identify specimens using several code numbers, as they have been entered into different databases since their collection. The Natural History Museum of Geneva (MHNG) gave the first code (a sample code), which consists of an area and year abbreviation. The Museum of Comparative Zoology (MCZ) DNA database logs whole collections with identification codes that consist of the prefix "MCZ DNA" and a six-digit number. A Biota database (Colwell, 2004) for Cyphophthalmi in the Giribet Laboratory at the MCZ gives each specimen a different six-digit ID number, with the prefix "SPM." Moreover, this species described here was also used earlier in phylogenetic analysis under the moniker "Peninsula sp. 18" (Clouse *et al.*, 2009; Clouse & Giribet, 2010).

Appendage measurements were not always possible for certain specimens: the first (proximal) cheliceral article must be removed to measure its full length, trochanters can be broken when legs are removed, some individuals have injured or deformed appendages, and in this species in particular, the chelicerae are usually pulled tightly under the overhanging anterior edge of the dorsal scutum, obscuring the dorsal crest. Chelicera depth was measured just proximal to the dorsal crest to a point between the first and second ventral process. The depth of the fourth tarsus was measured on the proximal side of the adenostyle base.

TAXONOMY

FAMILY STYLOCELLIDAE

Leptopsalis foveolata sp. n.

Figs 1-34

HOLOTYPE: MHNG sample TH-99/4, MCZ DNA101093, MCZ Cyphophthalmi database SPM003920; Sai Khao Waterfall, Mt Sankalakheeree, Namtok Sai Khao National Park, ca 20 km NW of Yala city, Pattani Province, Thailand, 6°39'18.5"N, 101°5'50.5"E, 260 m; male; 22-X-1999, leg. P. Schwendinger.

PARATYPES: MHNG sample TH-99/4, MCZ DNA101093, MCZ Cyphophthalmi data-base SPM003917-9 (Figs 1-3); 3 males; same data as for holotype. – MHNG sample TH-99/4, MCZ DNA101093, MCZ Cyphophthalmi database SPM003921-4 (Figs 4-6); 4 females; same data as for holotype. – MHNG sample TH-99/5, MCZ DNA101496, MCZ Cyphophthalmi data-base SPM004415; 1 female; 23-X-1999, 260-350 m, otherwise same data as for holotype.

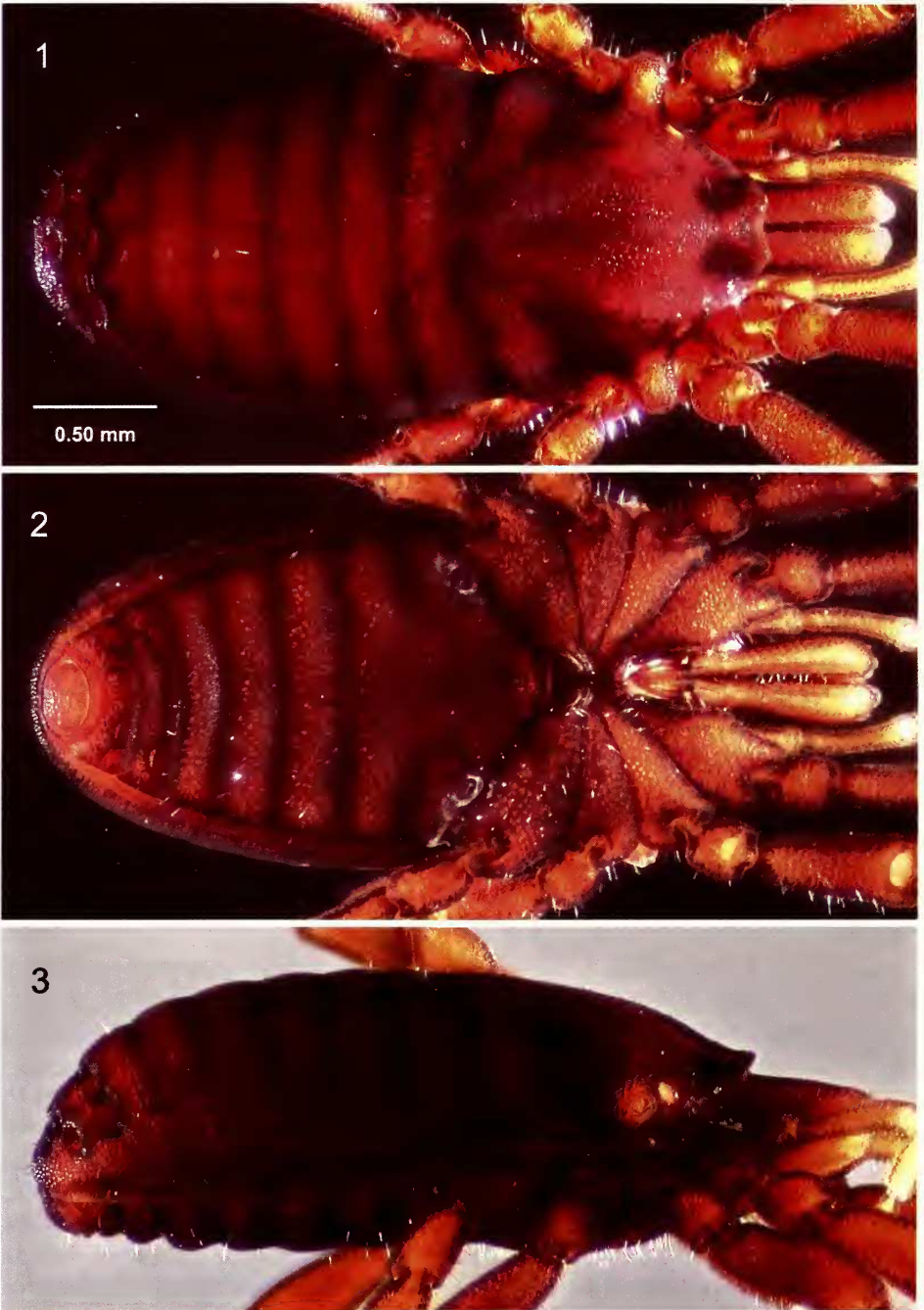
DEPOSITION AND PRESERVATION OF TYPES: All types are deposited in the MHNG except those used for SEM (SPM003918-9), which are deposited in the MCZ Cyphophthalmi SEM collection. Male paratypes SPM003918-9 were mounted for scanning electron microscopy, male paratype SPM003917 and female paratype SPM003922 were dissected to examine genitalia, and female paratypes SPM003921, SPM003922, SPM003924, and SPM004415 had DNA (remaining in MCZ) extracted and sequenced for phylogenetic studies (Clouse *et al.*, 2009; Clouse & Giribet, 2010).

DESCRIPTION: Body length (3.27 mm) of male holotype 2.13 times the maximum width (1.53 mm), equal across the ozophores and the second opisthosomal segment.

Dorsal scutum (Figs 1, 4, 7): Transverse prosomal-opisthosomal sulcus and opisthosomal sulci distinct; mid-dorsal, longitudinal opisthosomal sulcus absent. Anterior margin of prosoma meeting cheliceral ridge with protruding, weakly bilobed lip, rising gradually; entire scutum weakly arched.

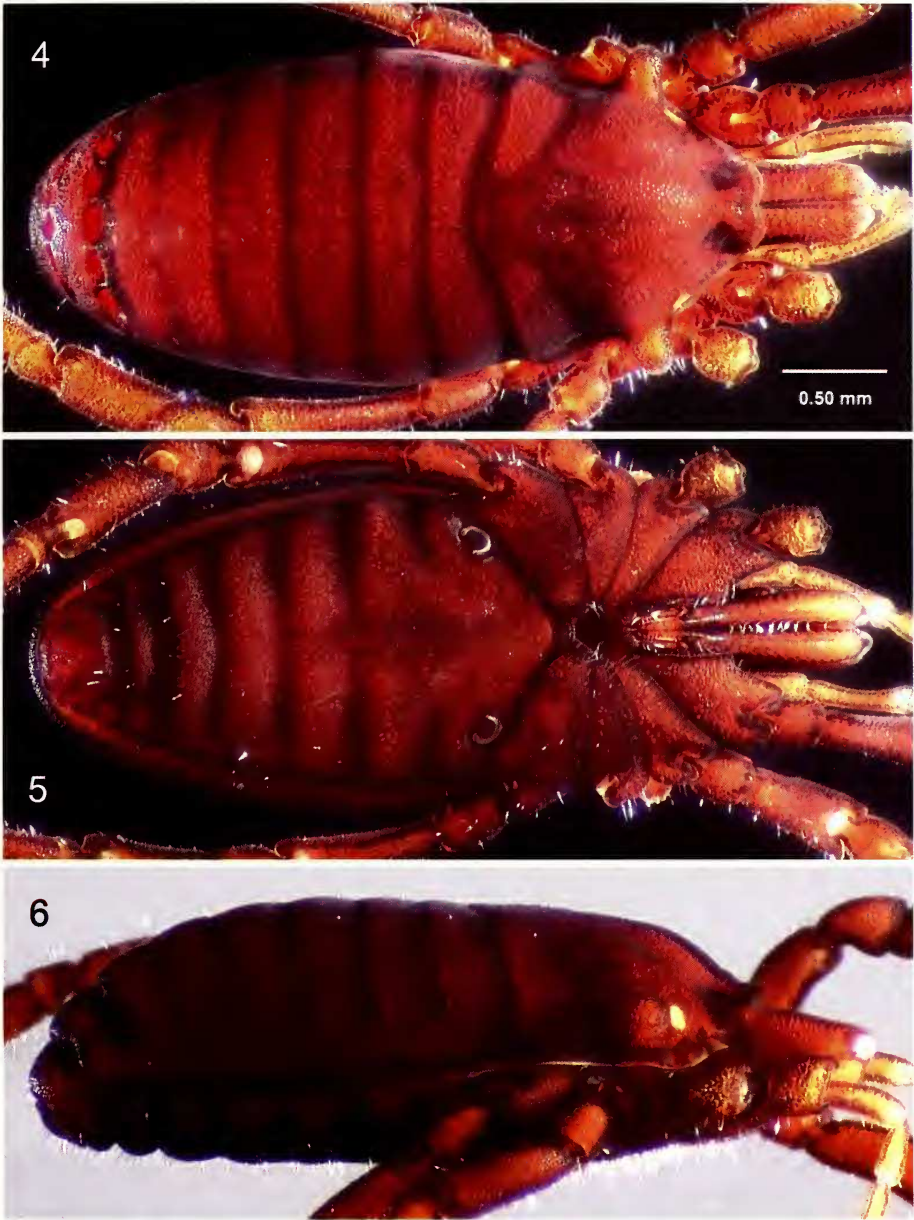
Ventral opisthosoma (Figs 2, 5, 8): Transverse sulci shallow and granular, complete after sternite 3, especially shallow between sternites 3 and 4; first three sulci after tergite 3 weakly sinoidal, medial region bending forward about as far as lateral ends. Sutures between tergites 6 and 7, and 7 and 8 gently curved back laterally.

Pits: Posterior opisthosomal sulci of males and females with deep, granular pits (Figs 7-12), these not corresponding to either tuberculate or microgranular integument ornamentation described by Murphree (1988). Dorsal pits mostly along sulci between tergites VI and VII and between tergites VII and VIII, numbering five in each row (Figs 7, 12). Sulcus between tergites V and VI granular, with small depressions. Ventral pits more irregular, along anterior edges of sternites 7 and 8, resembling deep, uneven folds along the sutures, forming two rows of five and six pits, respectively (Figs 8, 11).



FIGS 1-3

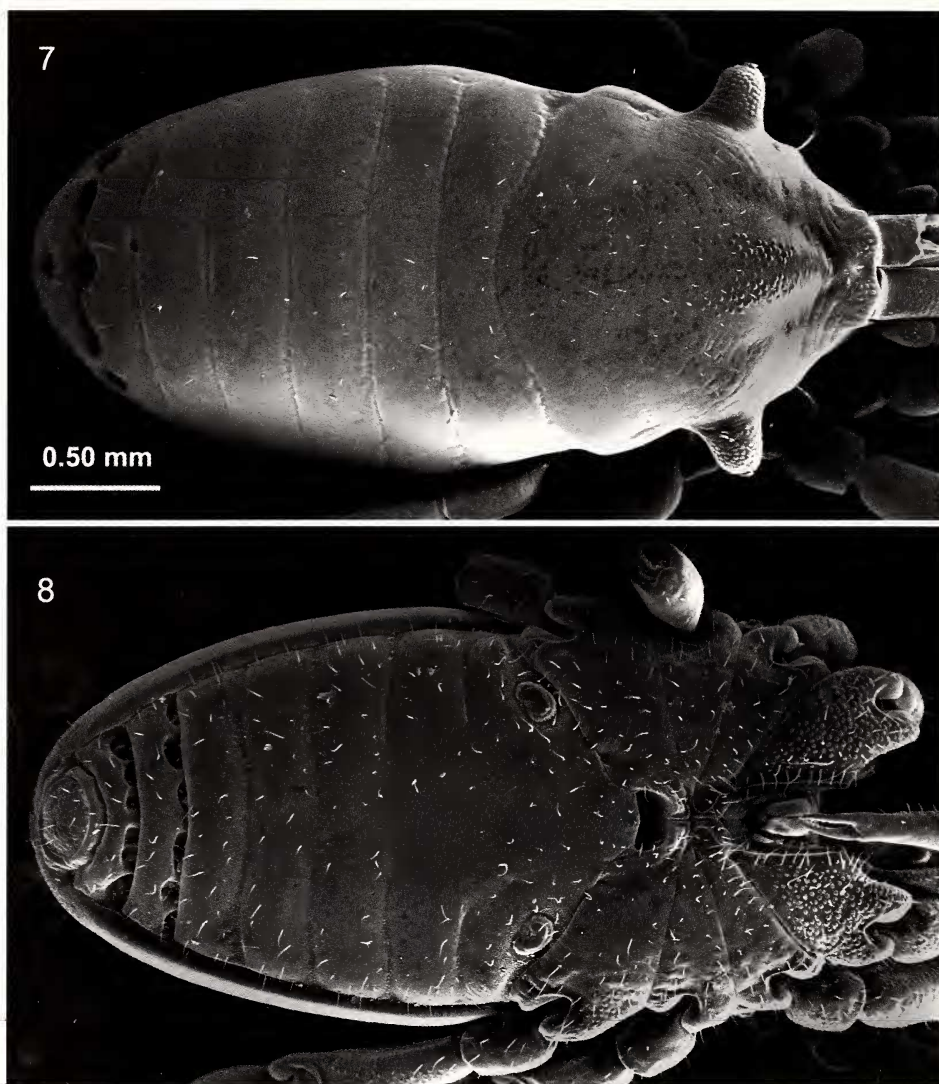
Leptopsalis foveolata sp. n., male paratype SPM003917. (1) Dorsal view. (2) Ventral view. (3) Lateral view.



FIGS 4-6

Leptopsalis foveolata sp. n., female paratype SPM003922. (4) Dorsal view. (5) Ventral view. (6) Lateral view.

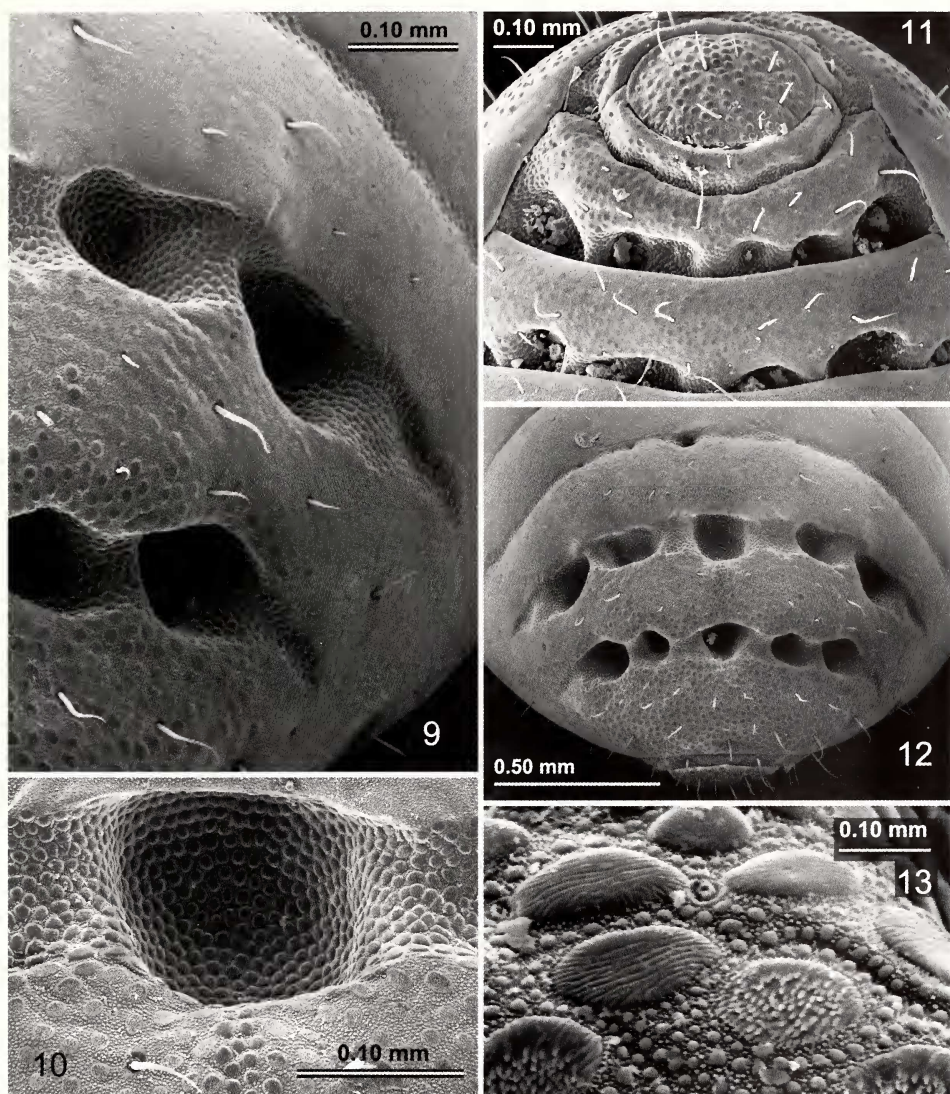
Tergite IX and sternite 9 with wrinkled, granular edges opposite anal plate (Figs 8, 19). Pits densely covered with large granules, lacking large pores or other structures (Fig. 10).



FIGS 7-8

Leptopsalis foveolata sp. n., scanning electron micrographs of male paratypes SPM003919 and SPM003918, respectively. (7) Dorsal view. (8) Ventral view.

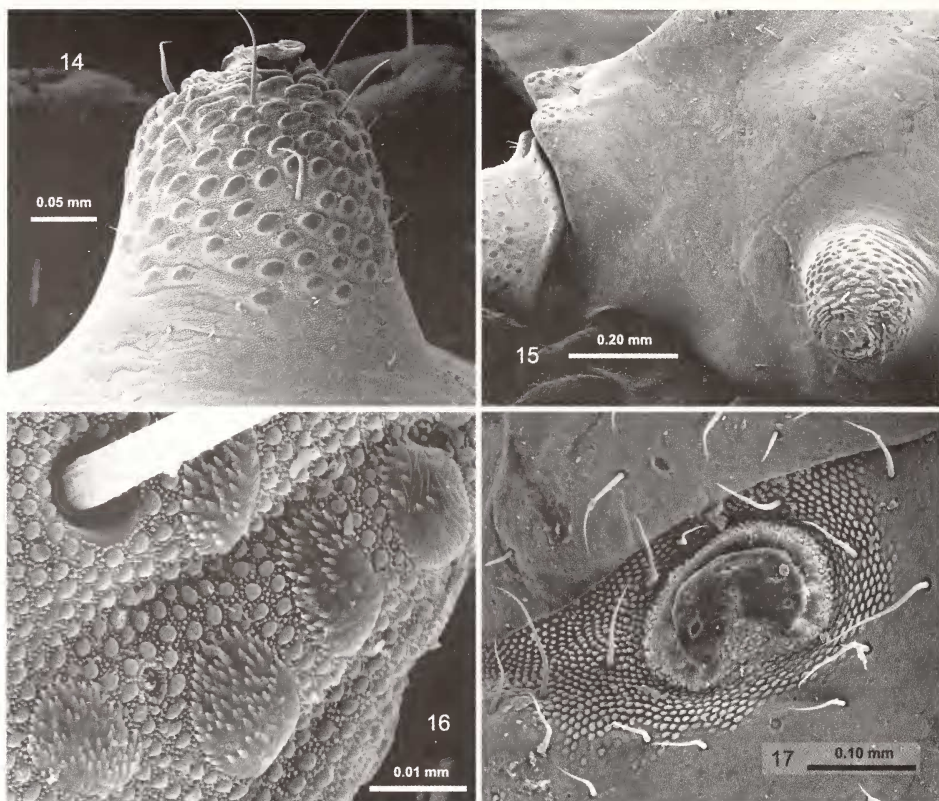
Ozophores, eyes, and sculpturing: Ozophores lateral, raised above carapace edge ("type 2" of Juberthie, 1970), large, tapered, pointing anteriad (Fig. 14). Eyes distinct, large, with cornea, positioned anterior to ozophores (Fig. 15). Integument uniformly microgranular but lacking larger tubercles except in particular locations. Large tubercles of two types: raised, smooth and flattened; and rough, digitate. Transitional tubercles also present around pits (Figs 13, 16). Raised tubercles on dorsal, anterior



FIGS 9-13

Leptopsalis foveolata sp. n., magnified views of pits of male paratypes SPM003919 (9-10, 12-13) and SPM003918 (11). (9) Dorsal pits dorsolaterally on right side. (10) Central pit between tergites VI and VII. (11) Ventral pits and anal region. (12) All dorsal pits. (13) Transition of granule morphology along lower left lip of central pit seen in Fig. 10.

edge of carapace; on distal $\frac{3}{4}$ of ozophores; on central anterior, dorsal prosoma; starting in posterior half and center of tergite VII through tergites VIII and IX; sparsely distributed in center of tergite VI; inside sulcus between tergites V and VI; on anal plate; sparsely distributed on sternite IX; inside, between and lateral to dorsal and ventral pits; inside ventral opisthosomal sulci; on coxae I and extreme distal anterior



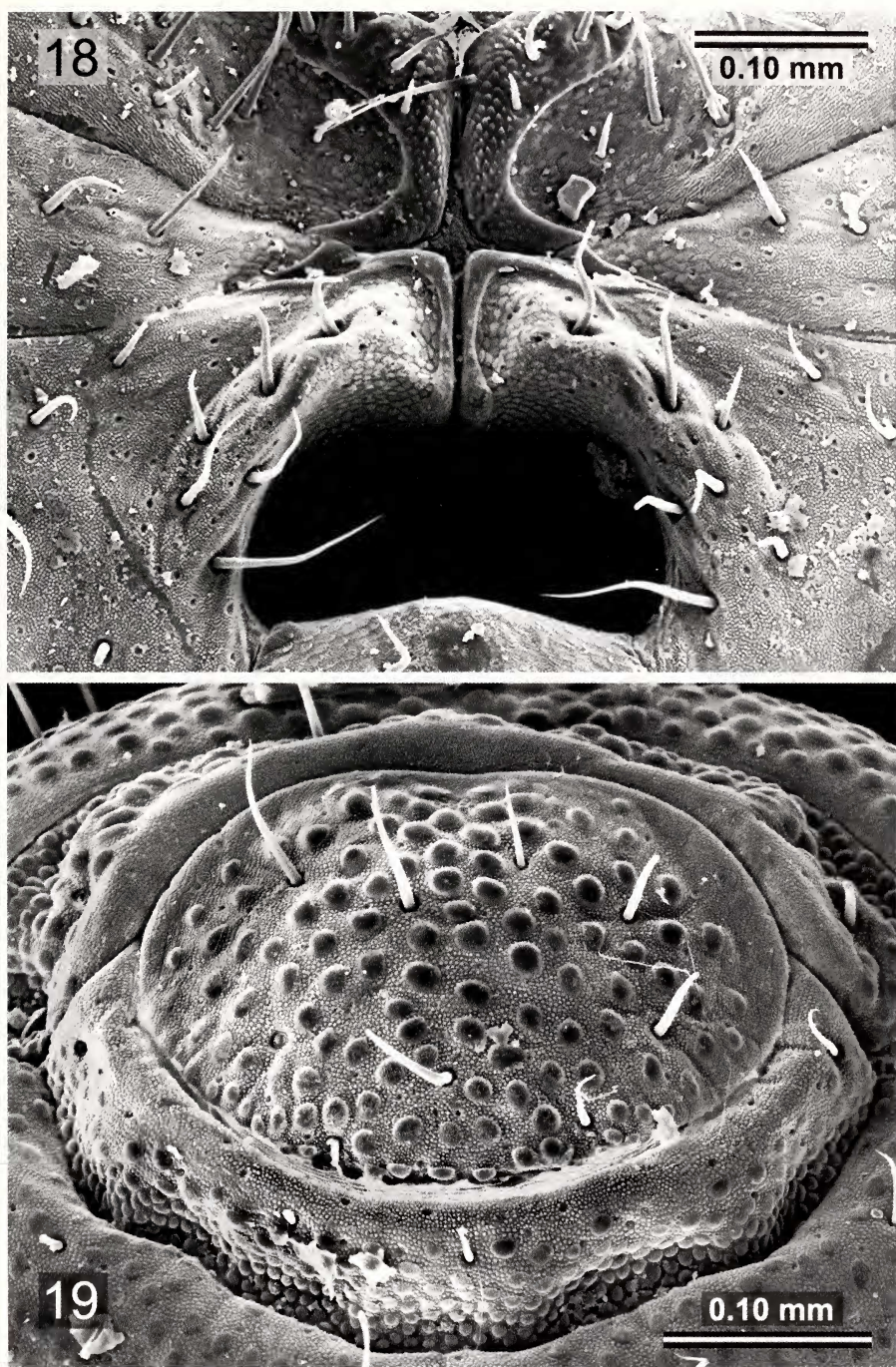
FIGS 14-17

Leptopsalis foveolata sp. n., male paratype SPM003919 (14-15) and male paratype SPM003918 (16-17). (14) Ozophore, dorsal view. (15) Base of chelicera, anterior margin of dorsal scutum, eye and ozophore, lateral view. (16) Transition of granule morphology along edge of ventral pit. (17) Spiracle.

of coxae IV; and on all articles of all appendages except third article of chelicerae. Large flattened, digitate granules found in three longitudinal rows on dorsal side of prosoma; anterior to prosomal-opisthosomal sulcus; starting on tergite VI to anterior of tergite VII; and starting laterally on sternite 3, increasing through sternite 9.

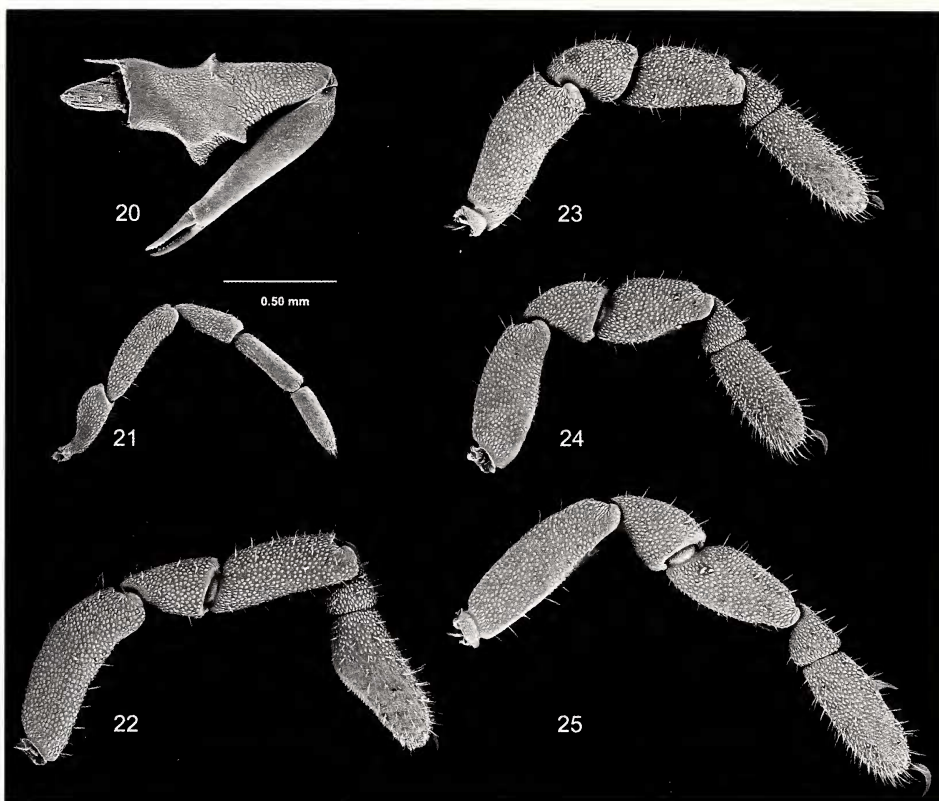
Ventral prosomal complex (Fig. 18): Coxae IV meeting along midline for distance equal to length of gonostome; coxae III not meeting, with weak sternum between proximal ends; contact zone between coxae II longer than that between coxae IV, with endites more than twice as large as those on coxae IV. Gonostome wider than long, evenly arched to rectangular anteriorly; first opisthosomal sternite slightly rounded anteriorly, forming weakly concave posterior edge of gonostome; lateral walls formed by distinct, elevated posteroproximal processes of fourth coxae, these most elevated on anterior edge.

Anal region (Figs 11, 19): Sternites 7, 8 and 9 and tergite IX free; tergite IX wider than sternite 9, both with densely and coarsely granular, uneven surface opposite



FIGS 18-19

Leptopsalis foveolata sp. n., male paratype SPM003918, details of ventral side. (18) Gonostome and ventral prosomal complex. (19) Anal region.



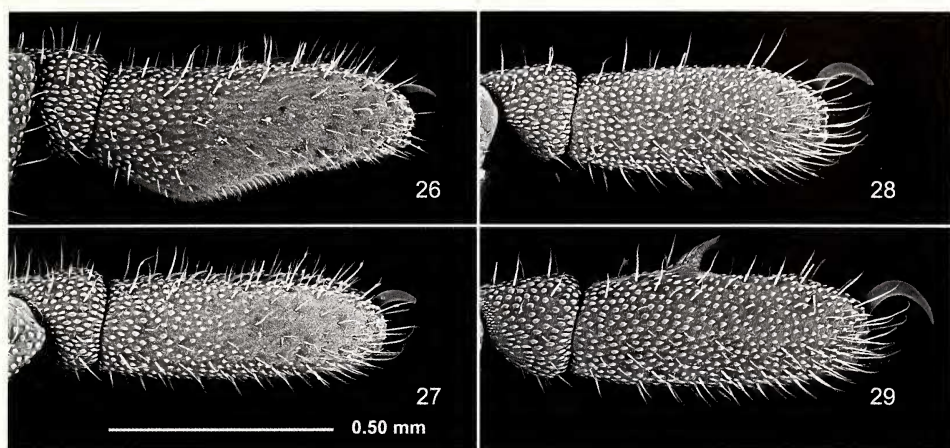
FIGS 20-25

Leptopsalis foveolata sp. n., appendages of male paratype SPM003918, lateral views. (20) Chelicera. (21) Palp. (22) Leg I. (23) Leg II. (24) Leg III. (25) Leg IV.

anal plate; microgranular, even surface flush along edge of anal plate. Tergite VIII lacking gland pore; anal plate with large, raised granules and irregularly convex surface.

Chelicera (Fig. 20): Third article (movable finger) about one-fourth length of second article, second article gradually narrowing for distal two-thirds of length. First article with distinct dorsal crest, ridge flattening laterally and visible only as smooth area leading to distinct, moderately-sized second ventral process. Dorsal crest often not visible in specimens, usually pulled under anterior edge of dorsal scutum. First (proximal) ventral cheliceral process distinct, slightly larger than second (distal) ventral process. First article with large, evenly spaced granules laterally and dorsally after dorsal crest. Second article with some distinct granules at curve to proximal joint; irregular, flattened granules laterally in proximal half; remainder of second article and third article smooth.

Palp and legs: Palp granular from trochanter to proximal fourth of article IV, without process on trochanter (Fig. 21). Leg I granular to proximal third and dorsal surface of tarsus (Fig. 22); leg II granular to proximal half, dorsal and ventral surfaces of



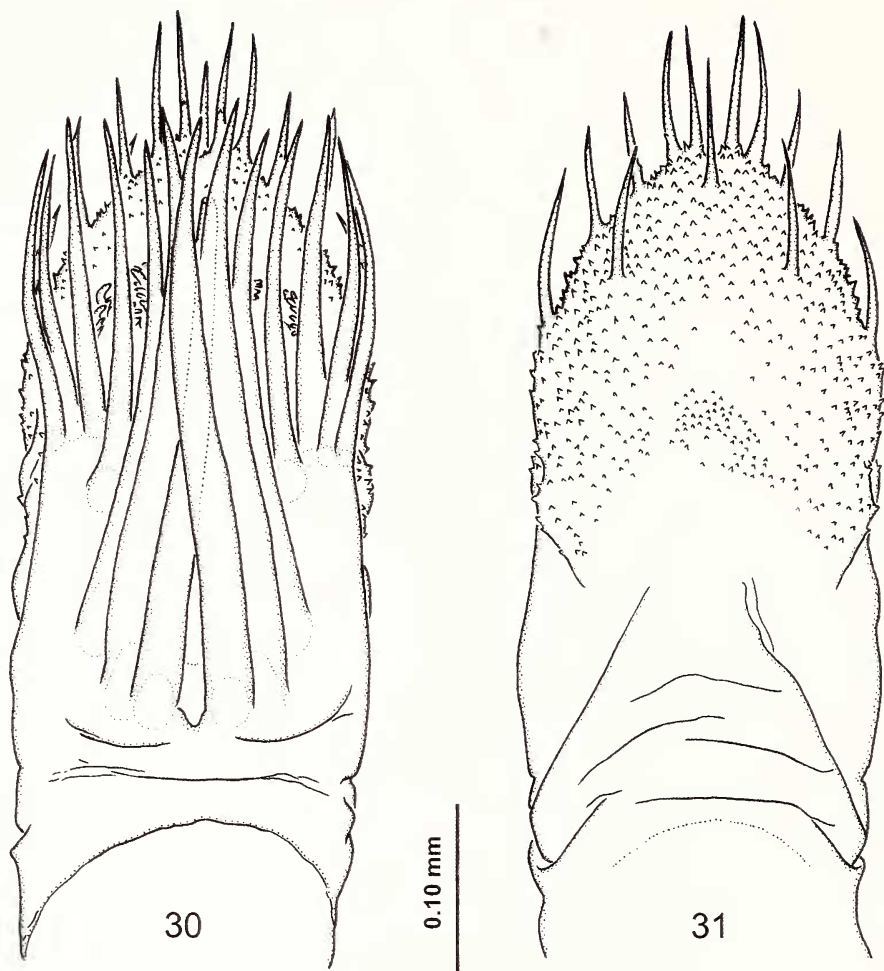
FIGS 26-29

Leptopsalis foveolata sp. n., leg tarsi of male paratype SPM003918, lateral views. (26) I. (27) II. (28) III. (29) IV.

tarsus (Fig. 23); legs III and IV completely granular (Figs 24-25). Tarsus of leg I with distinct solea extending two-thirds length of tarsus (Fig. 26). Medial dorsal surface of tarsi of legs I and II with solenidia (a row of evenly spaced, curved, blunt-tipped sensory hairs; see Willemart & Giribet, 2010), these situated more distally on tarsus I; areas around solenidia generally without granules (Figs 26-27). Tarsus of leg IV evenly granular; depth even for most of its length; adenostyle located at 30% of tarsus length from the proximal end, its tip pointing distally (Fig. 29).

Spermatopositor: Microtrichia formula: 3, 10, 7+7; dorsal microtrichia on two or three different levels, medial three on each side attached distinctly proximally to the lateral four, these about half the length of the former; ventral microtrichia on two levels, medial one near apex of spermatopositor, lateral two more than halfway down to level of most lateral apical microtrichia; four apical microtrichia arranged in two pairs on either side of shallow, apical, medial invagination; remaining six apical microtrichia evenly spaced along sides to just distal of widest point; microtrichia with few denticles proximal on their shafts. Ventral surface of spermatopositor with numerous denticles (Figs 30-31). Gonopore complex with broad lobus medialis lacking lateral processes; short lobuli laterales present, distinctly proximal, not reaching base of lacinia dorsalis, the latter extending distally to just beyond distal edge of lobus medialis, flanked by curved digiti extending the same length as lacinia dorsalis (Fig. 32).

Ovipositor (Figs 33-34): Two apical lobes, each with several setae over whole surface, ending in apical seta; a pair of setae lightly shorter than the apical ones just subapical on each lobe; more subapically a sensitive process containing a dense set of slightly curved, shorter and furcate setae. Distinct pigmented bodies in distal half on prolateral side of each apical lobe. (These pigmented bodies have meanwhile also been found in another *Leptopsalis* sp. and in *Stylocellus globosus* Schwendinger & Giribet in Schwendinger *et al.*, 2004, and are thus not apomorphic for *Fangensis* as postulated



FIGS 30-31

Leptopsalis foveolata sp. n., spermatopositor of male paratype SPM003917. (30) Dorsal view. (31) Ventral view.

by Schwendinger & Giribet, 2005). Ventroproximal plates narrow, somewhat triangular, less wide than apical lobes and half their length, carrying three setae each. A pair of sac-like receptacles near base of each apical lobe.

VARIATION: Females are about 9% longer and wider than males, but have the same body proportions. Among males, body size varies by almost 20%, and among females by around 13%. The longest specimen is female paratype SPM004415 (3.68 mm), which is 25% longer than the smallest male and relatively narrower than other specimens (length 2.3 times the width across the ozophores versus average of 2.1

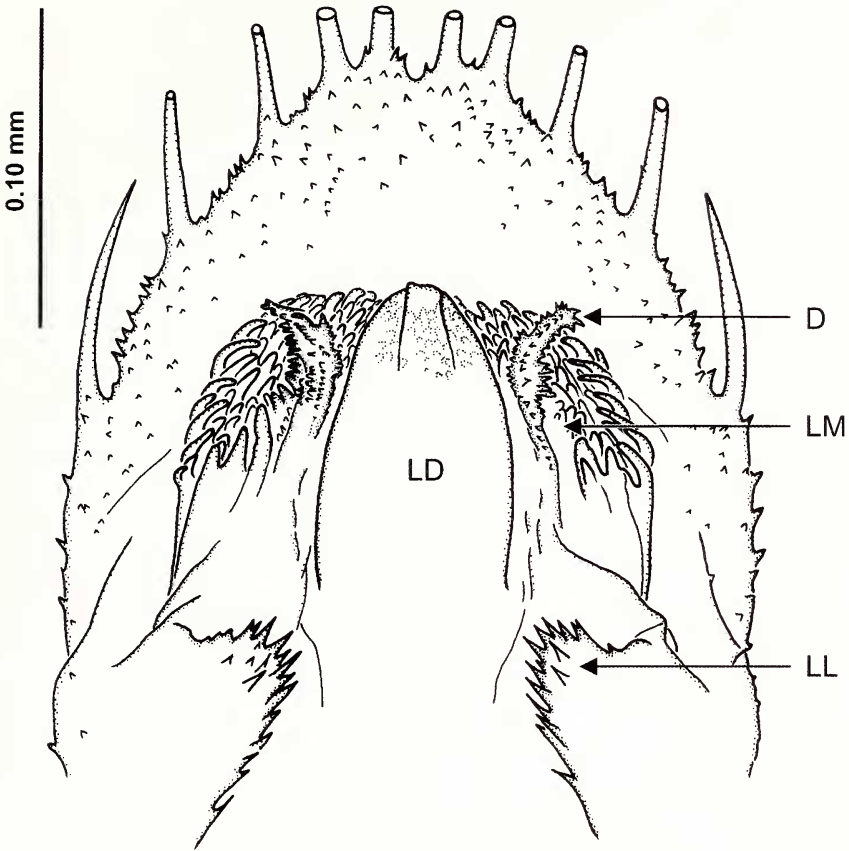
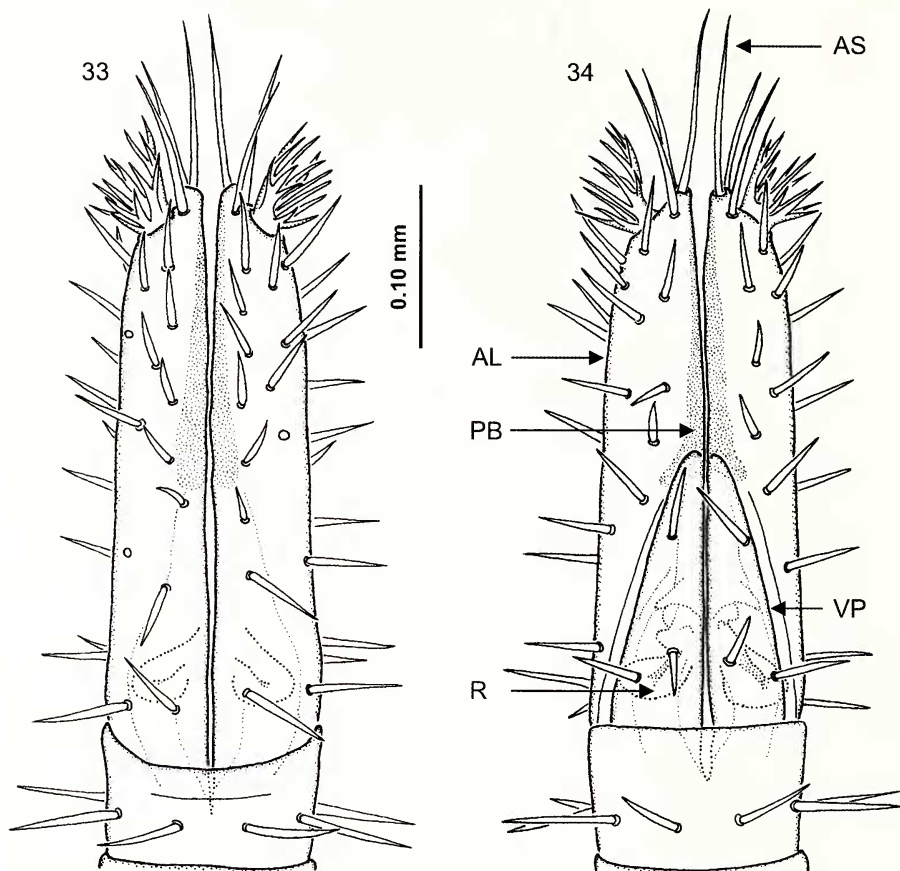


FIG. 32

Leptopsalis foveolata sp. n., gonopore complex of male paratype SPM003917, dorsal view. D = digitus, LM = lobus medialis, LL = lobulus lateralis, LD = lacinia dorsalis.

for males and 2.2 for other females). The number of opisthosomal pits varies as follows: Two male and two female paratypes have 1-2 small but deep pits in the sulcus between tergites V and VI (Fig. 12), others have none. Males ($n=4$) have five large pits in the sulcus between tergites VI and VII, and between tergites VII and VIII, females ($n=5$) have 5-6 large pits in each of these sulci. Males have six pits between sternites 6 and 7 and 4-6 pits between sternites 7 and 8, females have 3-6 pits in each of these sulci.

DISTRIBUTION AND HABITAT: The new species is known only from the type locality. The types were collected by sifting and extracting (in Winkler/Moczarski soil extractors) leaf litter and humus from close to the Sai Khao waterfall, in primary lowland rain forest. Soil extractions (by the same method) below the waterfall, along a small side-branch of the stream, in July 2011 yielded no additional specimens.



FIGS 33-34

Leptopsalis foveolata sp. n., ovipositor of female paratype SPM003922. (33) Dorsal view. (34) Ventral view. AL = apical lobe, AS = apical seta, PB = pigmented body, R = receptacle, VP = ventroproximal plate.

DISCUSSION

The literature on Cyphophthalmi systematics has included a rich discussion of their morphological features, and several taxonomic groups have remarkably clear morphological synapomorphies (de Bivort & Giribet, 2004; Giribet & Boyer, 2002; Willemart & Giribet, 2010). Many of these are sexually dimorphic, and of these, most consist of male opisthosomal gland pores and associated modifications such as depressions, apophyses, or “hairy” structures called scopulae. In Stylocellidae, opisthosomal gland pores occur in some species as a single opening on tergite VIII, which is nearly always associated with a longitudinal strip of modified sculpturing on the anal plate. Also, exclusive to Stylocellidae is another sexually dimorphic gland opening, this one on the ventral surface of the male first tarsus in *Fangesis cavernarum* Schwendinger & Giribet, 2005 (see Willemart & Giribet, 2010).

TABLE 1. Lengths, widths (only when specified) and proportions (in brackets) of bodies (= dorsal scuta) and appendage articles of the male holotype and male and female paratype averages. Body proportions are of the dorsal scutum length divided by the corresponding width measurements [across widest part of the body (not counting the ozophores), and across the ozophores], and appendage proportions are the lengths divided by the depths.

A - male holotype [ratio]

Body	Length	Width (body)	Width (across ozophores)			
	3.27	1.53 [2.14]	1.53 [2.14]			
	Trochanter	Femur	Patella	Tibia	Metatarsus	Tarsus
Leg I	0.31 [1.10]	0.89 [2.82]	0.51 [1.71]	0.69 [2.40]	0.27 [1.05]	0.76 [2.31]
Leg II	0.26 [1.06]	0.76 [2.41]	0.47 [1.43]	0.60 [1.91]	0.27 [1.12]	0.66 [2.70]
Leg III	0.23 [0.89]	0.76 [2.52]	0.37 [1.13]	0.51 [1.80]	0.23 [1.07]	0.66 [3.29]
Leg IV	0.33 [1.15]	0.89 [2.82]	0.50 [1.59]	0.65 [1.99]	0.26 [1.00]	0.73 [2.43]
Chelicera	I (crest)	I (whole)	II	III		
	0.60 [1.68]	—	1.17 [7.46]	0.30 [7.50]		
Palp	Trochanter	Femur	Patella	Tibia	Tarsus	
	0.33 [2.30]	0.56 [3.55]	0.36 [2.7]	0.41 [4.14]	0.34 [3.43]	

B - male average [ratio] (n = 4)

Body	Length	Width (body)	Width (across ozophores)			
	3.18	1.51 [2.11]	1.52 [2.10]			
	Trochanter	Femur	Patella	Tibia	Metatarsus	Tarsus
Leg I	0.32 [1.02]	0.83 [2.96]	0.47 [1.50]	0.66 [2.12]	0.25 [1.09]	0.71 [2.39]
Leg II	0.25 [0.97]	0.72 [2.58]	0.42 [1.31]	0.54 [1.69]	0.25 [0.99]	0.64 [2.84]
Leg III	0.23 [1.06]	0.70 [2.71]	0.36 [1.23]	0.51 [1.55]	0.23 [1.30]	0.60 [2.76]
Leg IV	0.32 [1.27]	0.86 [2.90]	0.45 [1.37]	0.59 [1.71]	0.25 [0.98]	0.70 [2.52]
Chelicera	I (crest)	I (whole)	II	III		
	0.56 [1.60]	0.94 [2.49]	1.11 [6.45]	0.27 [6.28]		
Palp	Trochanter	Femur	Patella	Tibia	Tarsus	
	0.32 [2.30]	0.54 [3.77]	0.32 [2.43]	0.38 [3.78]	0.31 [3.02]	

C - female average [ratio] (n = 5)

Body	Length	Width (body)	Width (across ozophores)			
	3.46	1.64 [2.11]	1.57 [2.21]			
	Trochanter	Femur	Patella	Tibia	Metatarsus	Tarsus
Leg I	0.29 [1.02]	0.87 [2.96]	0.45 [1.50]	0.59 [2.12]	0.26 [1.09]	0.74 [2.39]
Leg II	0.26 [0.97]	0.73 [2.58]	0.40 [1.31]	0.49 [1.69]	0.23 [0.99]	0.66 [2.84]
Leg III	0.28 [1.06]	0.74 [2.71]	0.37 [1.23]	0.47 [1.55]	0.28 [1.30]	0.61 [2.76]
Leg IV	0.33 [1.27]	0.84 [2.90]	0.44 [1.37]	0.53 [1.71]	0.23 [0.98]	0.71 [2.52]
Chelicera	I (crest)	I (whole)	II	III		
	0.58 [1.89]	—	1.10 [6.51]	0.27 [6.37]		
Palp	Trochanter	Femur	Patella	Tibia	Tarsus	
	0.30 [1.98]	0.51 [3.44]	0.33 [2.55]	0.37 [4.14]	0.34 [3.62]	

Stylocellidae has two other exclusive features that are sexually dimorphic but not readily associated with glandular secretions: Rambla's organ, which is a modified patch of cuticle on the retrolateral side of the fourth tarsus of males in several species (see Rambla, 1994; Schwendinger & Giribet, 2005), and a row of spines on the ventral surface of the first tarsus of *Stylocellus globus*, which is denser in males than females (Willemart & Giribet, 2010). The feature we describe here, the deep pits near the posterior end of males and females of *L. foveolata* sp. n., is also not apparently glandular in function but is additionally not sexually dimorphic. The only indication that these pits are associated with a liquid is the modification of granules along the posterior edge of each pit row, the grooves and digitate surfaces perhaps used to channel and disperse some compound. The one special feature in Cyphophthalmi this most resembles is Hansen's organ, which is an irregularly grooved raised area of cuticle found on the coxae and more distal leg articles of both males and females in the African genus *Ogovea*. Like Rambla's organ, Hansen's organ has micropores but is not clearly glandular in function (Giribet & Prieto, 2003; Willemart & Giribet, 2010).

Sexually dimorphic features are rare in *Leptopsalis*, the only occurrence being the anal gland pore in a few of the early lineages of the family (Clouse, in press; Clouse *et al.*, 2009). This suggests that there has been a profound behavioral shift in the genus whereby such features are not needed, despite living in a wide variety of habitats and radiating into the largest clade in the family. The pits described here in *L. foveolata* sp. n. show no difference between males and females, and may indicate an adaptation to some novel selection pressure at the type locality. Living near a waterfall, do these animals experience flooding and need these pits to channel water or trap air bubbles? But why then only at their posterior end? If anything, this novel structure highlights how much more there still is to discover about Cyphophthalmi behavior and ecology.

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